THE PRESENT SALINITY POSITION IN THE RIVER MURRAY BASIN

By K. O. COLLETT*

ABSTRACT: It is desirable that the salinity of water supplied from the River Murray should not often exceed 800 EC units. This is approximately the limit for irrigated stonefruit and overhead sprayed citrus, and for domestic use. In dry years this level of salinity has been exceeded in the lower reaches of the river.

The effect of river impoundment and diversion has been to reduce *average* flows to South Australia, so raising the salinities experienced in most years. In the post-Darmouth era, diversions will be increased by only a relatively small percentage.

Regulation of the river by storages, by ensuring reasonable flows, has removed the threat of experiencing extremely high salinities in *drought* years, as was the case with the river unregulated. Dartmouth will further improve this situation.

River salinity records obtained at Mannum (S.A.) since 1941 show a rising trend, which, although hard to quantify, indicates a possible increase in salt accessions each year of about 11,000 to 25,000 tonne/year. This trend is obviously due to irrigation activities causing increased salt returns to the river. Catchment deterioration could also be playing a part.

Some works to reduce salt accessions to the river have already been undertaken. These have tended to be at sites where large reductions have been gained with modest expenditure. Further interception and diversion schemes will generally be less effective in terms of tonnes of salt diverted per dollar spent.

The extensive irrigated regions in New South Wales and Victoria are experiencing a rapid increase in the area with high water tables, which cause salinisation of surface soils. If unchecked this will have a serious effect on the productivity of the regions, and their ability to support decentralized populations will decline. Some proposals to control the problem have been put forward, but disposal of saline groundwater from works which might be undertaken is a major problem. A scheme proposed by the Victorian Water Commission for part of the Shepparton Region would involve disposal of some moderately saline groundwater to the River Murray, with subsequent offsetting of the rises in river salinity by increased diversion of Barr Creek and evaporative disposal in Lake Tyrrell. New South Wales and South Australia have indicated that they do not agree with the concept of using the Barr Creek/Lake Tyrrell scheme only to restore 'status quo' salinities.

All three States are now moving towards a joint consideration of the total salinity problem in the Murray Basin, with a view to producing co-ordinated strategies for salinity control.

INTRODUCTION

The River Murray functions both as a source of supply and as a drainage course for a large part of northern Victoria and southern New South Wales, and is the major source of water supply in South Australia.

There are two distinct aspects to the question of salinity in the Murray Basin. The first is the salinity of water supplied from the river, whilst the second is the salinisation of irrigated land caused by the development of high water tables.

This paper reviews the current situation and makes some forward projections. Necessity for future co-ordination of the salinity control strategies of all three States is highlighted.

In August, 1967, the River Murray Commission engaged the consulting engineering firm of Gutteridge, Haskins and Davey to carry out a comprehensive investigation of salinity in the Murray Valley. The report of the study was published in 1970. In this paper reference is made to Gutteridge, Haskins and Davey as the

* Designing Engineer, State Rivers and Water Supply Commission, 590 Orrong Road, Armadale, Victoria 3143.

Consultants. New South Wales and Victoria are termed the upper States (relative to the direction of flow of the Murray River).

Salinities have been expressed in terms of electrical conductivity at 25°C (microsiemens/centimetre), commonly known as EC units. Salinities in mg/l or p.p.m. were converted to EC units where necessary by dividing by 0.6. The unit megalitres/day has been used for instantaneous flow rates, and also some average flows have been expressed in this unit, which is easier to relate to conditions on the Murray River.

SALINITY LIMITS FOR ESTABLISHED USES

Before studying salinity levels along the Murray River, it is desirable to consider salinity limits for established uses, to serve as comparative levels. It is recognized that there is really no sharp division between acceptable and unacceptable salinities, and that economic losses increase steadily as salinity rises. Nevertheless, there are salinity levels which, if exceeded, would be cause for concern, and these are referred to in this paper.

The salinity of water supplies can be a problem in all three States, but especially in South Australia, where the major uses are (a) irrigation of high value horticulture and (b) domestic and industrial water supply. For the horticulture, which comprises citrus, stonefruit and vines, the Consultants gave two salinity limits, one based on a consideration of the effect in the root zone of the total dissolved salts, the other on the effect of the chloride content. This latter limit was converted to a limit in terms of total salinity by using a ratio of chloride to total salts of 0.4. The Consultants' recommendations (which have been converted here from TDS to electrical conductivity values) are given in Table 1. The significant value in the Table is the limit of 725 EC units for stonefruit.

In addition to the limits in Table 1, which assume that furrow or low-throw sprinkler application is used, there is another limit for citrus (and stone-fruits) watered by overhead sprays, as it has been shown that chloride uptake by citrus trees is greater with this mode of application. It has been suggested that the appropriate salinity limit for overhead sprayed citrus is 800 EC units (Magarey 1977).

Almost 50% of the South Australian horticultural plantings are citrus and stonefruit and a significant proportion of these plantings have overhead sprays. From the foregoing, it is therefore apparent that salinities in the range 725 to 800 EC units mark the limit of acceptability for a large part of the South Australian irrigated areas.

For domestic use the desirable maximum salinity is 835 EC units (Gutteridge, Haskins & Davey 1970, E.W.S.D.(S.A.) 1976). The domestic aspect particularly concerns South Australia, where Murray water not only supplies towns along the river but also augments the water supply to most other towns and cities. In Adelaide, Murray water has averaged one quarter of the total supply in recent years, and in the 1967/68 drought year 80% of the water consumed in Adelaide came from the Murray. As urban populations grow, augmentation from the Murray will become increasingly important.

For the purposes of this paper, limits for horticulture and domestic supply have been rounded off to give, as the river salinity level which should not often be exceeded, a common value of 800 EC units.

SALINITY ALONG THE RIVER MURRAY

LONGITUDINAL SALINITY PROFILE

River salinities from Hume Dam to the mouth are measured regularly, and Fig. 1 shows the arithmetic average of these salinities at points along the river for a recent four-year period with a typical range of flows (solid line) and for a 10-month dry period (dashed line) when, for most months, flows to South Australia were down to levels of entitlement under the River Murray Waters Agreement (Appendix A). Both these longitudinal salinity profiles have a similar shape, with salinities higher in the dry period.

Both profiles show that the river salinity is low until the Loddon River confluence is reached. Here water from Barr Creek, which is the main drain of a surface drainage network serving about 125,000 ha of salt-affected farmland in the Kerang Region, enters the Murray. It is the biggest point source of salt along the river, and as shown in Fig. 1, causes a marked salinity jump. It should be noted, though, that works which have been constructed to divert Barr Creek flow to nearby Lake Tutchewop for

TABLE 1
LIMITING VALUES OF SALINITY FOR WATER
SUPPLIED TO HORTICULTURE
(expressed in terms of EC units)

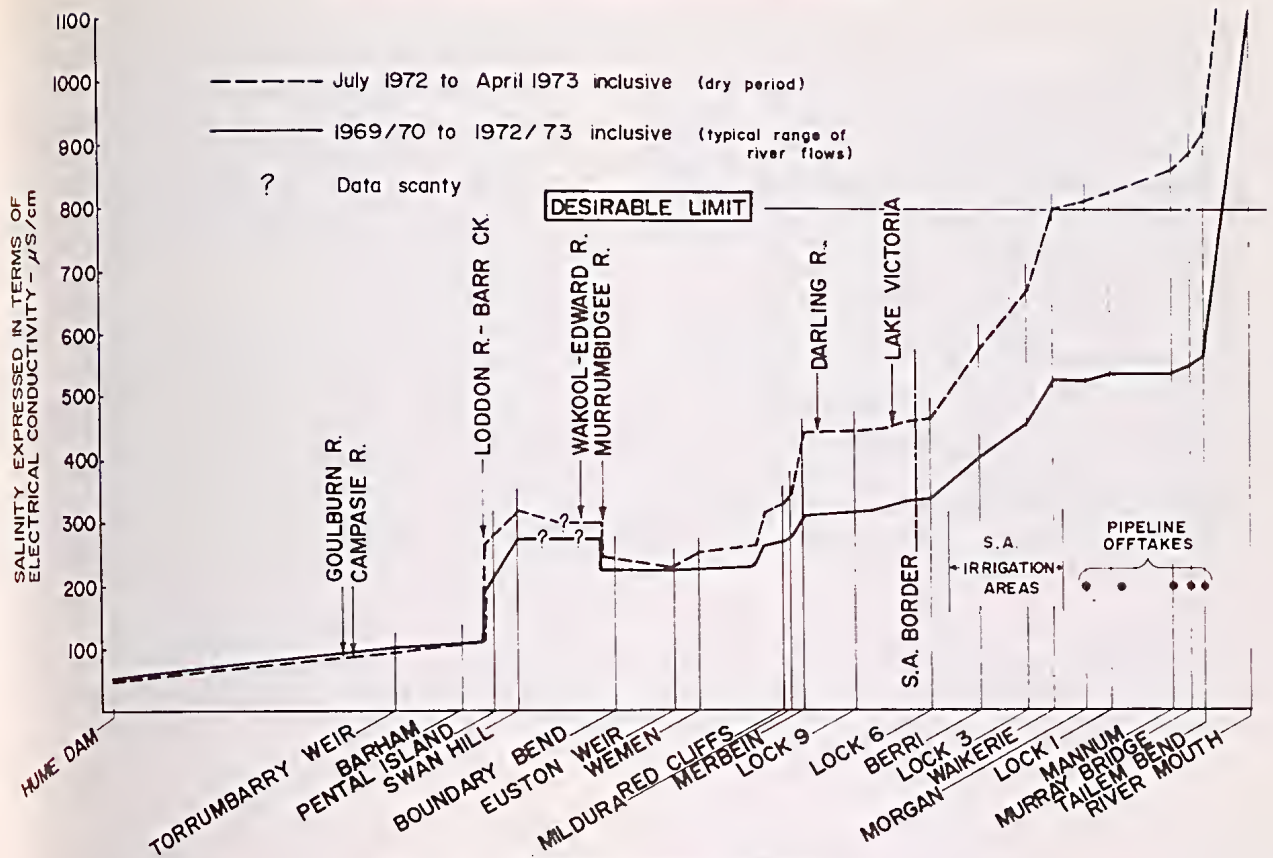| Based on:	Citrus	Stonefruit	Vines
Consideration of effect of total dissolved salts	1000	1000	1750
Consideration of effect of chloride content	1100	725	1450

FIG. 1 — Longitudinal Salinity Profiles.

evaporative disposal, although limited by evaporative capacity to only about 15% of the creek flow in the long term, can divert much larger proportions in dry periods, and can significantly reduce the salinity jump.

A further rise is shown occurring between the Loddon River confluence and Swan Hill. This is due, in part, to some of the Barr Creek salt load not joining the mainstream until just upstream of Swan Hill.

The next major input is from the Wakool River, which carries a salt load about half that of Barr Creek. The main source of salt in the Wakool appears to be groundwater which seeps in along the deeply incised lower reaches (Gutteridge, Haskins & Davey 1970). Its contribution to river salinity can be masked by significant flows of Murray water passing down the Edward River and diluting Wakool flows before they join the Murray.

Proceeding downstream, a significant diluting effect due to the Murrumbidgee River flow is noted.

Major salt accessions occur just upstream of Red Cliffs, and in the 20 km between Mildura and Merbein. The latter accession is the result of groundwater seepage from mounds built up beneath irrigated areas.

Another concentrated groundwater accession occurs between Locks 6 and 9, where Lake Victoria, an offstream storage, has raised groundwater levels adjacent to a number of side channels of the River Murray.

The major South Australian irrigation developments adjoin the River Murray in the Lock 6 to Waikerie reach. Here, as Fig. 1 shows, substantial increases in river salinity occur. Some of the causes of this are:

(a) irrigation induced accessions in the form of seepage from mounds beneath irrigated areas, seepage from drainage evaporation basins, or drainage basin overflows,
(b) subsurface flows brought about by hydraulic gradients created by weirs and locks,
(c) natural groundwater inflow.

Downstream of the principal irrigated areas the salinity rises further, but at a lesser rate, to Tailem Bend. Beyond this point, evaporation from Lakes

Alexandrina and Albert increases the salinity dramatically.

It can be seen from Fig. 1, that in the 10-month period selected for study, the average river salinity towards the downstream end of the South Australian irrigated areas approached the limit of 800 EC units. Moreover, at the principal urban supply pipeline offtakes further downstream, this limit was exceeded by up to 125 EC units.

River Murray salinity levels are therefore of great concern to South Australia, especially as salinities can be higher than the averages given in Fig. 1. For example, at Morgan, which is just downstream of the irrigation developments, and which is also the site of the first major pipeline offtake, the average monthly salinity equalled or exceeded 900 EC units for four of the months in the 10-month dry period, compared with the average for Morgan of 814 EC units.

RELATIONSHIP BETWEEN FLOW AND SALINITY

In the upper reaches of the river its salinity is derived from rock weathering, and does not vary much with flow. This is illustrated by the curve of salinity versus flow for Torrumbarry in Fig. 2.

The accessions further downstream tend to maintain a salt load input which, generalizing broadly, remains constant regardless of river flow variations. In the lower reaches, therefore, river salinity rises as flow decreases, and *vice versa*. The curve for Lock 6, at the South Australian border, shows this (Fig. 2).

It is of interest to study the average flow at a number of points along the river for the 10-month dry period July 1972 to April 1973. These are set out in Table 2. The diluting effect of the Murrumbidgee River is clearly shown by the increase in flow between Wakool Junction and Boundary Bend. It will also be noted that a large flow disappears between Lock 1 and the Murray River mouth. Diversions in this reach, including those to Adelaide, account for only 10%. The major loss is accounted for mainly by evaporation from the lakes at the mouth. This evaporation, which is estimated to average about 2,000 Ml/d, and which has been allowed for in the established river regula-
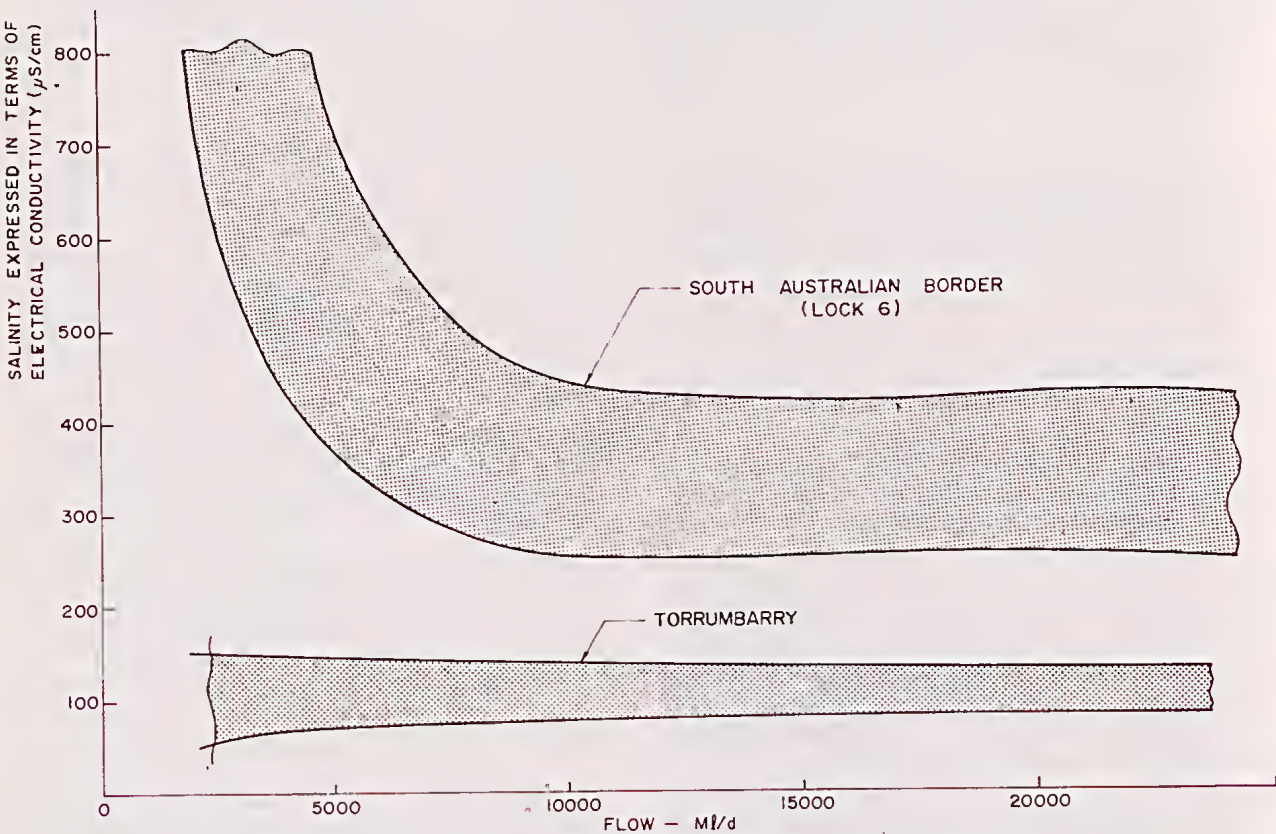

FIG. 2 — Salinity versus Flow at Torrumbarry and the South Australian border.

TABLE 2
AVERAGE FLOW IN RIVER MURRAY JULY 1972 TO APRIL 1973

Station	Average Flow (Ml/d)	Major Tributaries	Major Offtakes
Heywoods	11,000		
		Kiewa River	
Doctors Point	12,000		
Corowa	11,800		
		Ovens River	Mulwala Canal
			Yarrawonga Main Channel
Yarrawonga	9,000		
Tocumwal	8,300		
			Edward River
Barmah	5,200		
		Goulburn River	National Channel
		Campaspe River	
Torrumbarry	5,400		
Barham	5,300		
		Loddon River/Barr Ck.	
Swan Hill	4,800		
		Wakool/Edward River	
D/S Wakool Junct.	5,300		
		Murrumbidgee River	
Boundary Bend	6,800		
Euston (Lock 15)	6,600		
Colignan	6,500		
		Darling River	
D/S Rufus River	6,000		
Lock No. 1	3,500		
River Mouth	250 approx.		

tion practices, effectively provides a diluting flow through to the lowermost reaches of the river.

EFFECT OF RIVER REGULATION ON SALINITY

Before significant diversions and impoundings began along the Murray River, the average annual flow to South Australia was about 12 million megalitres. (Some other estimates are higher, i.e. about 15 million megalitres.) Usage by the two upper States has now reduced this by more than half. What has been the effect on salinities in South Australia?

Fig. 3 shows both the monthly pattern of natural flow to South Australia (Heliwell 1963), and the present average monthly flows for a typical sequence of years (1967/68 to 1972/73). It will be noted that the activities in the upper States have resulted in large flow reductions in winter, spring and early summer. However, for a year in which flows approximate to the present winter-early summer flows of Fig. 3, salinities would be acceptable. Taking December as an example; average natural flow was about 50,000 Ml/d,

whereas flow now averages a little over 15,000 Ml/d. From Fig. 2, it can be seen that for flows at the border in excess of 10,000 Ml/d, salinities are generally low enough (300 to 400 EC units) to be of no concern to users, even with increases due to accessions further downstream. In post-flood situations, however, high downstream salinities can result from return flows of saline water from bank storage (see later, Effect of Flood Flows) even when salinities are in this range at the border.

Average flows have been reduced also during late summer and autumn, but again, for a year with flows approximating to the present flows of Fig. 3 salinities would be within acceptable limits, with the possible exception of January.

While average conditions are satisfactory, conditions in individual years may not be. A computer program developed by the River Murray Commission has enabled the operation of the present river system to be simulated for a period with the climatic and hydrologic conditions of 1895/96 to 1971/72. The results of this simulation have been used to prepare Fig. 4, which shows the
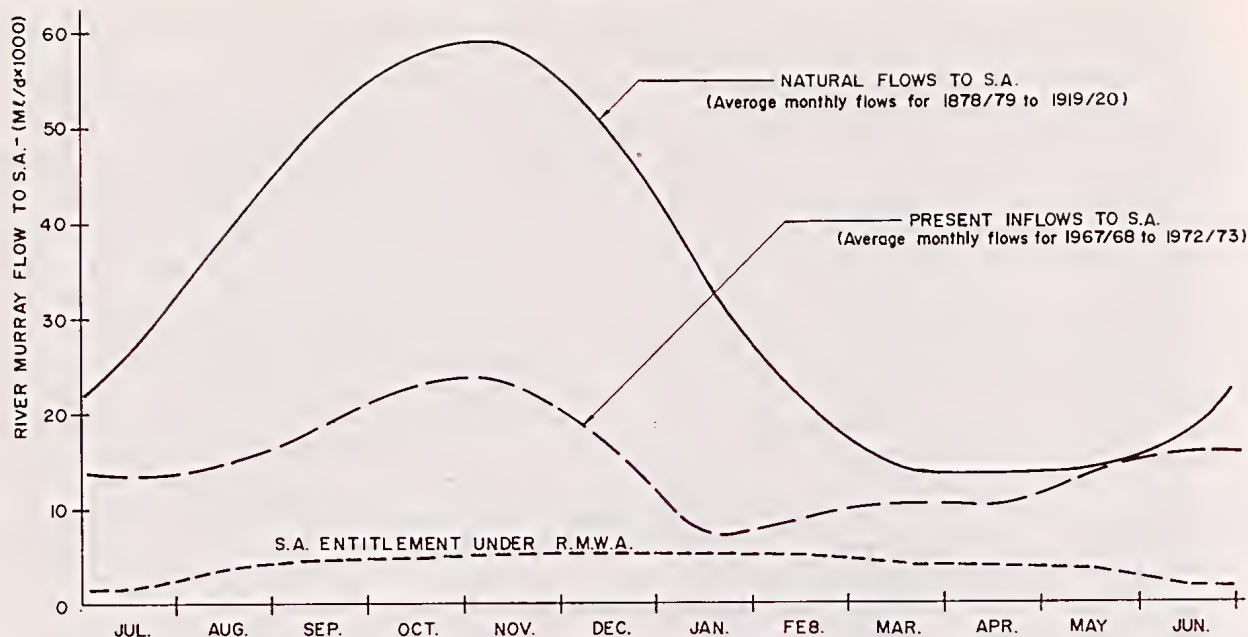
K. O. COLLETT

FIG. 3 — Effect of River Murray Regulation on Flow — average year.
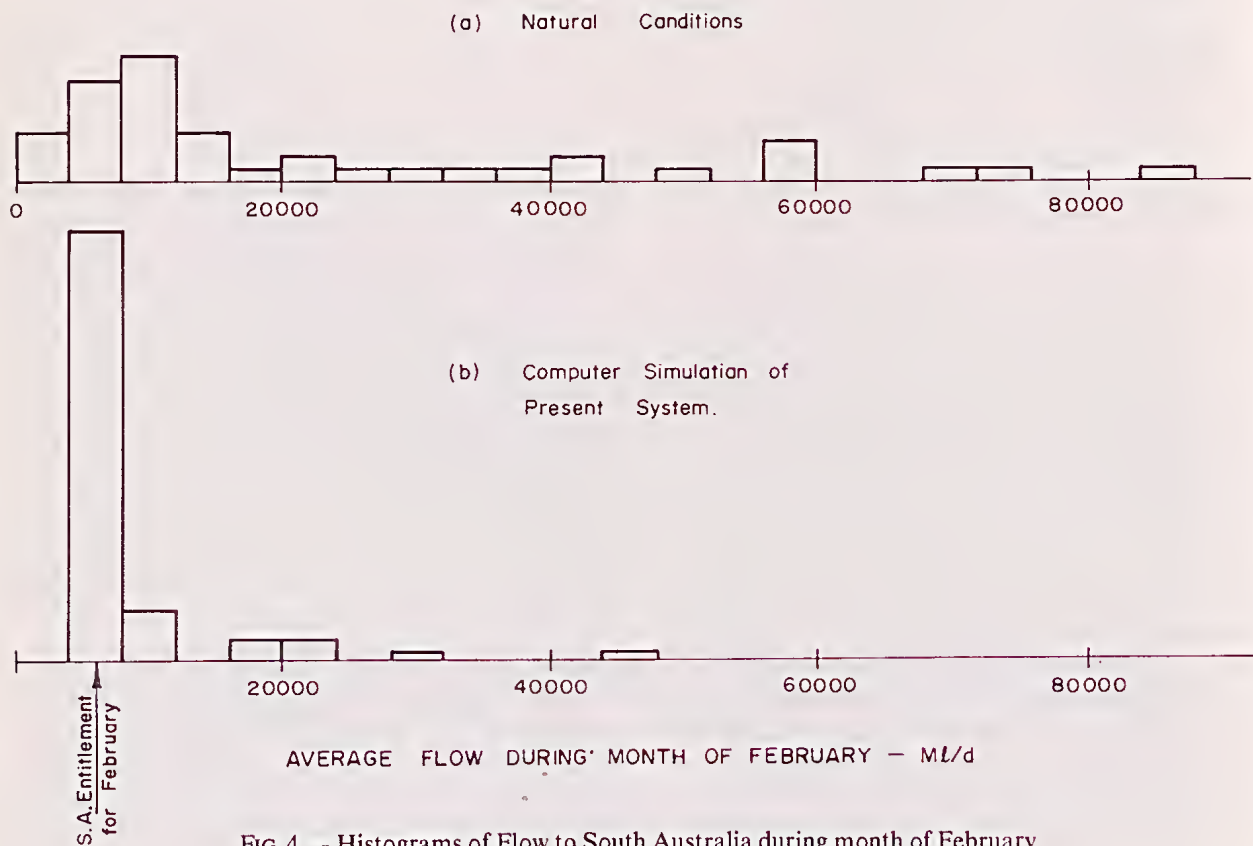

FIG. 4 — Histograms of Flow to South Australia during month of February.

distribution of flows to South Australia for the month of February, with the present degree of regulation and usage by the upper States. The distribution of natural flows is also shown for comparison. The figure illustrates the greater tendency for the present flows to lie towards the statutory entitlement, that is, towards the low flow end of the scale. Although February is used as an example, this pattern is repeated throughout summer/ autumn, and to a lesser extent in winter/ spring. With flows to South Australia equal to the present statutory entitlement, salinities in that State can, and do, exceed the limit of 800 EC units.

Flow reductions at the South Australian border due to the Dartmouth storage will not be great. The role of this reservoir is basically to safeguard existing development, and the average increase in diversions by the upper States will be in the order of only 0.5 million megalitres per year. This represents a 14% increase in the total annual diversion (averaged over the six year period from 1969/70 to 1974/75) from the River Murray, tributaries above Albury, and effluent streams below Albury.

However, one trend could be significant. In the past, uncommitted flows in the Murrumbidgee River have played an important role in providing dilution of the lower sector of the Murray. But irrigation development along that river in recent years has brought its water resources close to full commitment. The dilution potential of the still uncommitted flow is now regarded as only marginal during periods of high irrigation demand. This situation would be accentuated if additional en route Murrumbidgee storages were to be constructed.

One very notable effect of river regulation is the improved situation in *drought* years. For example, under natural conditions, in 1914/15, flows to South Australia dropped almost to zero, and river salinities of 7,000 EC units were recorded at Berri, rising to 10,000 EC units at Morgan, and 16,000 EC units towards Lake Alexandrina. The River Murray Commission computer simulation shows that with present storages and demand levels, and with a repeat of 1914/15 conditions, inflows to South Australia could be held at about 4,000 Ml/d for most months, as depicted in Fig. 5. Although salinities for much of the South Australian reach would be above the 800 EC limit under these flow conditions, the improvement over natural conditions is nevertheless dramatic. The further increases in flow under post-Dartmouth conditions, which have also been computer simulated, and

which are shown in Fig. 5 for 1914/15, are the result of:

(a) An increase in the South Australian entitlement, under the River Murray Waters Agreement, from 1.55 million Ml/year to 1.85 million Ml/year. This will have to be made available by the upper States unless a 'period of restriction' is declared.

(b) With Dartmouth in operation 'periods of restriction' could be less frequent, even with the increased South Australian entitlement. (Appendix A explains the meaning of the term 'period of restriction'. With the present degree of regulation and usage, the simulation showed that in a repeat of the period 1895/96 to 1971/72 (77 years), there would have been 18 years of restrictions).

The diluting effect of Dartmouth flow is particularly noticeable in December 1914 and January 1915 in the simulation. In these months, flow would be increased from 4,500 Ml/d to 7,000 Ml/d, and salinity at the border would reduce from about 600 to 400 EC units.

In short, the effect on the South Australian reaches of diversions and impoundings in the upper States has been to narrow the range of flows and salinities experienced.

SALINITY TRENDS

Annual values of salinity recorded at Mannum (S.A.) since 1941 show a rising trend of about 6 EC units/year, which is repeated in the five year moving average values (Toll & Trewhella 1977). In an average annual flow of (say) seven million megalitres, this represents a salt load increase of about 25,000 tonne/year, every year. It should be noted, though, that some part of the rising salinity trend could be attributable to increasing diversion of low salinity water for irrigation.

The figure for the rate of salinity increase must be treated with the greatest caution, as the position of drought years (high salinity) and flood years (low salinity) in the sequence has a great effect. One means of eliminating this effect is to consider salt loads for periods of (say) 10 years early in the sequence of years and towards its end. For the period 1963-72 the Mannum salt load (calculated using average annual values of flow and salinity) was 1,500,000 tonne greater than for the period 1941-50, even though the flow for 1963-72 was 15 million megalitres less than for the earlier period. It is reasonable to assume that had there been an additional flow of this amount, it would have comprised water from the upper catchments at about 70 to 170 EC units salinity, carrying a salt load of 1,000,000 tonne (say). Therefore, for equal flow volumes in the two 10-year periods, the difference
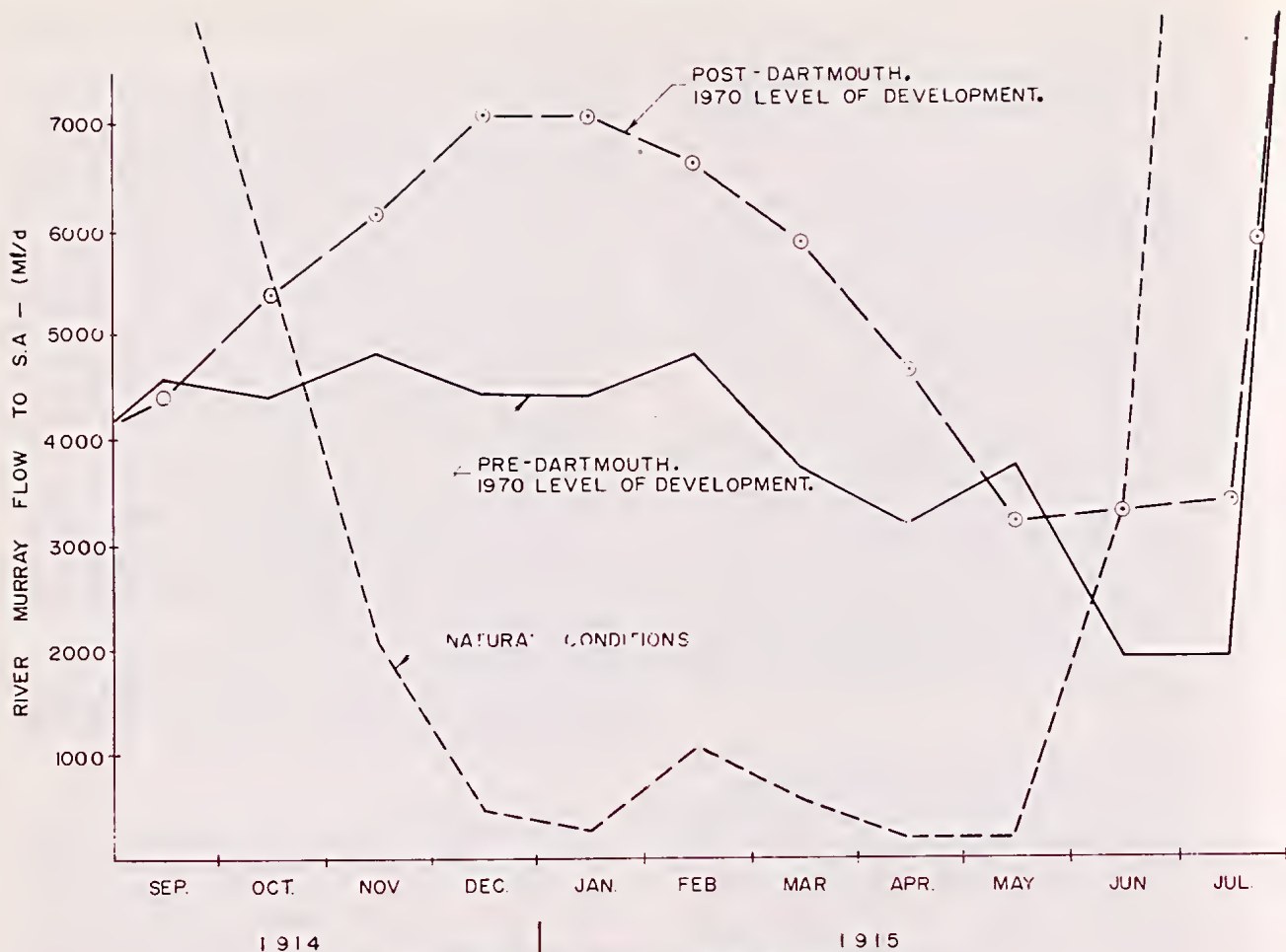
FIG. 5 — Effect of River Regulation on Flow — 1914/15.

in their salt loads would be about 2,500,000 tonne, that is, in one year the average salt load carried would be 250,000 tonne more in the latter period than in the former. Given that the mid points of the two periods are 22 years apart, it appears from this analysis that new accessions have been developing at the rate of about 11,000 tonne/year. Again, caution is necessary, as consideration of different periods can give quite large variations in the rate of increase of salt load. Nevertheless, it is clear that there has been a significant increase in salt load inputs in the last 35 years. Possible reasons for this are given later.

EFFECT OF FLOOD FLOWS

The salinities for the years 1957 and 1958 highlight an interesting phenomenon. Flows in these years were not unusually high or low, being 5.9 and 9.9 million megalitres respectively, at the South Australian border. In such years average Mannum salinities would normally be 350-400 EC units.

However, in 1957 the average Mannum salinity was 660 EC units while for 1958 it was 780 EC units. The explanation advanced is that 1956 was a year of prolonged flooding in which the river flow to South Australia totalled 54 million megalitres. This is believed to have caused extra storage of saline groundwater adjacent to the river, with consequent higher-than-normal accessions for some time after the flow recession.

Similar high salinities were noted following 1974, in which flow to South Australia was 35 million megalitres.

WORKS TO CONTROL SALINITY

The last 10 years has seen an increased awareness of the effects of high river salinities, with some works being undertaken specifically to reduce accessions. The extreme situation in the drought year of 1967/68 was one of the catalysts. Another was possibly the unfavourable economic forces

<div align="center">TABLE 3
WORKS TO CONTROL SALINITY
<i>(For a brief description of these works, refer to Appendix B)</i></div>

Scheme	Date of Construction	Capitalized Cost[1]	Tonne salt/year diverted	Capitalized Cost/ Tonne/year
Lake Victoria/Brilka Creek, Stage I (S.A.)	1967[2] (Temporary)	$90,000	27,000[3]	$3
Barr Ck./Lake Tutchewop (Vic.)	1968	$2,250,000	30,000	$75
Lake Hawthorn (Vic.)	1968	$1,735,000	11,000[3]	$157
Curlwaa I.A. (N.S.W.)	1973/74	$80,000	11,000	$7
Renmark Reservoir (S.A.) Stage I	1976/77	$60,000	24,000	$3
Mildura-Merbein Groundwater Interception (N.S.W. side)	Under construction	$625,000	27,000	$23
Mildura-Merbein Groundwater Interception (Vic. side)	Construction imminent	$1,235,000	25,000	$49
Noora Basin (S.A.) (Serving Renmark, Berri-Barmera, Cobdogla areas)	Possible scheme	$20,000,000	(a) 75,000 currently[4] (b) 130,000 in Year 2000[4]	$267 $154
Lake Tyrrell Scheme (Vic.)	Possible[5] Scheme	$30,000,000	100,000[6]	$300

Notes:
[1] Annual costs capitalized at 8% have been added to capital cost. Capital cost updated to present day level where necessary, assuming 10% inflation rate.
[2] Temporary works constructed in 1967. Capitalized cost refers to permanent works constructed in 1976.
[3] As well as diverting salt away from the river this scheme delays salt entry to the river until flows are adequate to dilute it.
[4] Maximum values. Lesser values apply in many years.
[5] The Victorian Water Commission has proposed that the Lake Tyrrell Scheme be constructed to offset the effect of outfalling Shepparton Region groundwater to the river.
[6] Additional to present diversions.

affecting agriculture generally, which could have made production losses more important to growers.

As might be expected, the situations where the maximum interception of salt can be gained per dollar spent have been tackled first, although some of the more cost effective measures have been implemented later because of the amount of investigation needed before proposals could be formulated.

Table 3, which lists the control works undertaken to date, shows the significant benefit obtained at modest cost so far. Also, two projects which might be undertaken are included to illustrate the higher costs of future works.

The schemes installed to date, together with those about to be constructed, have a combined salt interception capacity of 155,000 tonne/year. Assuming this was distributed evenly throughout the year, the combined effect with a river flow averaging 6,000 Ml/d past the sites of the schemes, as it did in the 10-month dry period reported earlier in this paper, would be a reduction in salinity of 120 EC units. Although this calculation is over-simplified, in that it ignores the effect of diversions, drainage returns, and inputs from the Darling River and Lake Victoria, it does suffice to show that the present works, together with those about to be constructed, can be a significant factor in maintaining acceptable salinity levels.

On a more pessimistic note, estimates (see earlier, Salinity Trends) for increases in salt accessions to the river are between 11,000 and

25,000 tonne/year. If increases are still occurring at this rate, the benefit of the 155,000 tonne/year capacity of the schemes will soon be nullified.

IRRIGATION AREAS IN THE UPPER STATES

So far this paper has concentrated on salinity from the point of view of the user of River Murray water for supply. This section covers the other major aspect, namely waterlogging and salinity problems brought about by high water tables beneath irrigated lands in the Murray Basin.

In Victoria and N.S.W. there are five major Irrigation Regions in the Basin; the Shepparton, Kerang, Murrumbidgee, Deniliquin and Wakool Regions. Their gross area is 1.75 million ha.

On a percentage area basis, pasture is the dominant irrigated culture in the Victorian Regions, but the relatively small area of horti-culture in the Shepparton Region has played a major part in its economy. For the Deniliquin and Wakool Regions the main enterprises are based on irrigated pastures, with rice growing also significant. The Murrumbidgee Region has an area of horticulture similar to Shepparton's, with the remainder of the irrigated area evenly divided between pasture and rice.

Irrigation has enabled the Regions to be settled more intensively than with dryland farming. For example, at the time of the 1971 Census, the Shepparton Region supported 70,000 people. Comparison with nearby 'dry' municipalities suggests that without irrigation this figure would be 30,000.

Works have been undertaken to cope with water table problems which have arisen in the Murrumbidgee Region, and disposal is believed to affect only slightly the Murrumbidgee River (and hence River Murray) quality. Discussion therefore centres around the other four Regions.

An estimate of the increase in the area of high water tables with time in the 'Do-Nothing' case, produced by the Consultants, is shown in Fig. 6. Although the estimate was based on incomplete data, and would probably be revised if the exercise were repeated using updated information, it is useful for indicating likely trends.

The Consultants' estimate was that for 1970 there would be 260,000 ha with high water tables, with 80% of this area in the Kerang Region. There has been evidence of high water tables and salinisa-tion in this Region since early this century. A con-sequence of the salinisation is the high salinity of runoff from surface drains, many of which were constructed in the 1930s.

According to the Consultants, the total area of high water tables will expand rapidly from 1975 onwards, with the Shepparton and Deniliquin Regions contributing the biggest increases.

In May 1975 the Victorian Water Commission (SR&WSC (Vic.) 1975) advanced a plan for the protection of the more intensively irrigated parts of the Shepparton Region from water logging and salinisation. This plan has since been developed in more detail. As the Shepparton situation is believed to be indicative of that which is developing, or will develop, in much of the area of the other Regions, it will be described at some length here.

A program for protection of horticultural areas (about 6,600 ha) by groundwater pumping is half completed, and the concern now is for 125,000 ha of intensively irrigated pasture land which either has a high water table, or is soon expected to develop one. The immediate effect of a high water table developing beneath an intensively irrigated pasture property is a productivity drop of five percent. Ultimately, this will become 25% as salinisation takes effect. It has been calculated that if this situation is allowed to develop the decline in productivity of the 125,000 ha will result in the Regional population being 5,550 people less than would be the case with no high water table. The proposal put forward involves the lowering of the water tables by 450 pumped tubewells in the pasture areas, in addition to the 150 now being installed in horticultural areas. Because the salinity of the extracted groundwater is comparatively low, it would be possible to re-use 50% of it by dilution through the supply channel system. The proposal is to outfall the remainder to the River Murray where the increased salinities should be acceptable down to the Loddon River junction (the average increase would be 75 EC units). From there on normal rises in Murray salinity make it desirable to offset the effect, and it is proposed that this be achieved by increasing the diversion of Barr Creek to 60% of its average annual flow, with evaporative disposal in Lake Tyrrell.

New South Wales has a proposal for the lowering of a highly saline groundwater mound which occurs under 40,000 ha in the Wakool Region. It is proposed to dispose of the extracted groundwater by evaporation, with harvesting of the sodium chloride and injection of the bitterns (1% of the original volume) into a deep aquifer.

Both New South Wales and South Australia have objected to the Victorian plans for the Shepparton Region as outlined above, the principal concern being that the Lake Tyrrell Scheme is
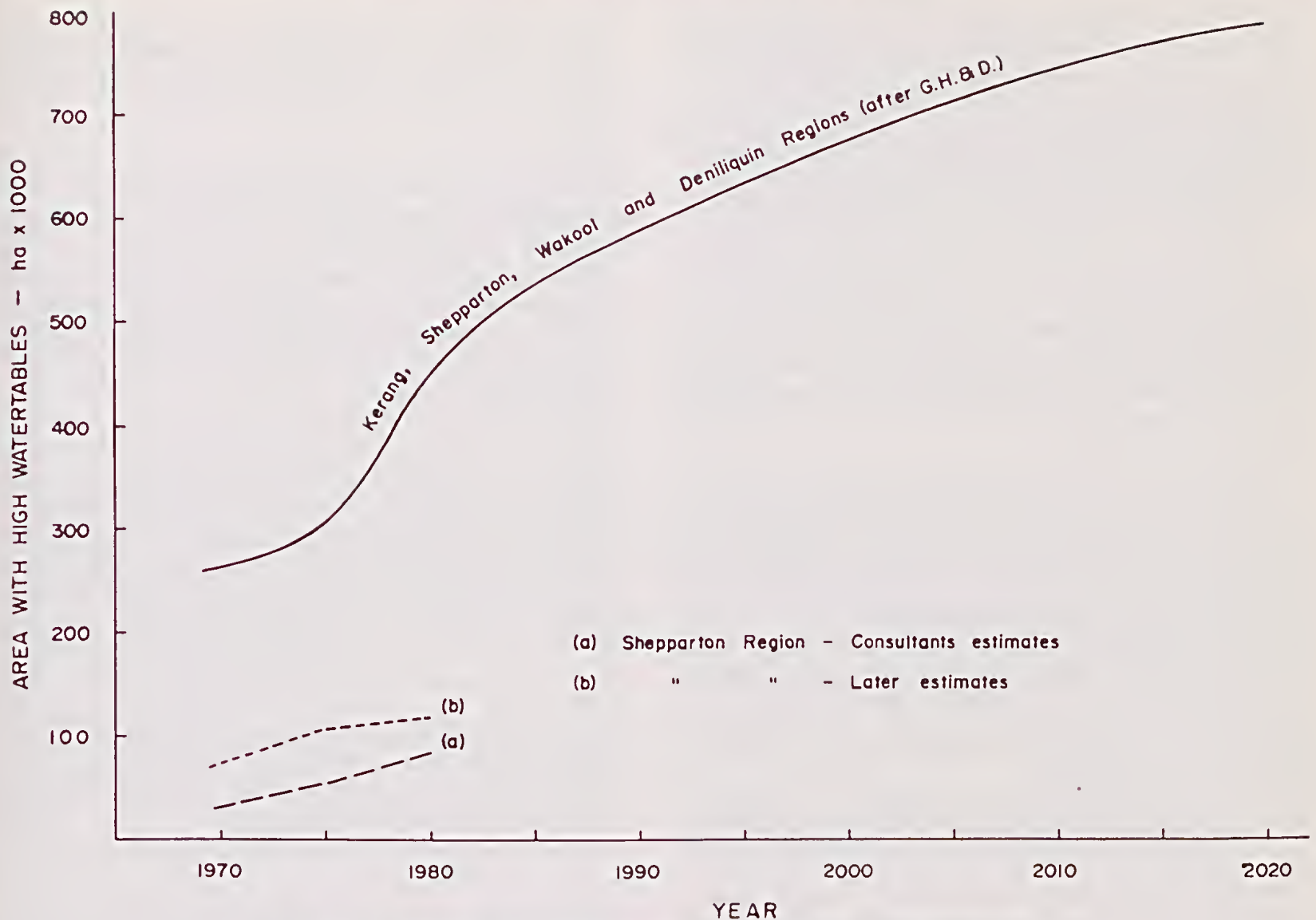
FIG. 6 — Predicted Increase in High Water Tables — Upper States.

proposed to be of a compensatory nature only. South Australia made the following points (E.W.S.D. (S.A.) 1976):

(a) River salinities already experienced can be higher than desirable limits,

(b) there is an apparent rising trend in salinity,

(c) there is a limit to the amount of salt diversion away from the River Murray which can be economically undertaken in South Australia, and,

(d) under these circumstances the acceptability of the Victorian proposal would depend upon Victoria's acceptance of the need for operation of the scheme to provide at all times acceptable salinities to South Australia, and demonstration by mathematical modelling that such operation is feasible.

The three States, through the River Murray Commission, are now moving towards a joint examination of their salinity problems. This is expected to include the development of a 'package' proposal of salinity control schemes, and possibly river regulation procedures, which will cope with the salinity problems of all parties. A ranking of the items in the package into priorities for implementation would also be part of the study.

POSSIBLE JOINT STUDY

Users of water from the downstream reaches of the river may be regarded as being subject to a 'squeeze', represented by the apparent narrowing gap between the desirable salinity limit and average levels already experienced. This squeeze is seen to be due largely to irrigation activities in all three States, which have had the effect of reducing flows in all except drought years, and increasing salt load inputs.

In the author's opinion several questions are pertinent. Firstly, what salt load, if intercepted and diverted away from the river, would hold the squeeze at an acceptable pressure? Secondly, how does this compare with the salt load which it is practicable to divert away from the river? Thirdly, is there also scope for offsetting salinity increases which may come from future drainage works in irrigation areas? Fourthly, if it is not practicable to divert sufficient salt load for both purposes, are

there other feasible measures which, together with salt load diversion, would have the desired effect? These measures could involve changes in the crops grown in irrigation areas supplied from the river, or changes in irrigation techniques. Fifthly, if this is not the case, which areas will have to accept less than desirable conditions of supply or drainage?

An obvious prerequisite for a study of salinity problems is a sequence of River Murray flows for use in simulation of the system behaviour. This sequence must represent expected future conditions of diversion and impoundment. Also, agreement will have to be reached on the degree of damage and economic loss which would be caused at various levels of river salinity.

Perhaps the most important point to resolve before commencing the study proper is the amount of salinity increase to be expected in future in the 'Do-Nothing' case. Factors which could have influenced the rate of rise in the past are:

(a) The opening up of new irrigation areas, with drainage disposal back to the river, either directly or indirectly. An example of indirect disposal is drainage to evaporation basins, close to the river, which leak or overflow.

(b) The intensification of irrigation in salinised areas, which has the effect of increasing saline drainage runoff. For example, between the early 1940s and the present, the amount of water applied to the Barr Creek catchment has increased by about 30%. Also, in both (a) and (b), diversion of water for irrigation would tend to increase river salinities by reducing river flow.

(c) The extension of surface or sub-surface drainage in areas with salinity problems. In some areas pumps extracting highly saline groundwater were allowed to discharge to surface drains.

(d) The salinisation of land already surface drained.

(e) The development of groundwater mounds beneath irrigated areas causing direct accessions by seepage.

(f) A general rise in water table levels in some areas traversed by the Murray and its tributaries, resulting from activities such as land clearing.

(g) The apparent increase in salinity of runoff due to deterioration of some catchments.

Clearly, the contributions of each of these factors will have to be quantified. Those factors which are likely to continue to cause rises will need to be identified, and taken into account in the formulation of a joint strategy.

ACKNOWLEDGMENT

APPENDIX A
THE PROVISIONS OF THE RIVER MURRAY WATERS AGREEMENT IN RELATION TO FLOWS TO SOUTH AUSTRALIA

The River Murray Waters Agreement specifies that a quantity of 1.55 million megalitres is to be allowed to pass into South Australia each year, in specified monthly amounts, monthly excesses not counting as part of the annual entitlement.

The Agreement requires the River Murray Commission to maintain certain reserves (1.23 million megalitres at present) in Hume Reservoir and Lake Victoria, for use in dry years. If the storages fall below the reserve quantity, the Commission is required to declare a 'period of restriction'. Also, in a drought year, the Commission may make such a declaration even if the storages exceed the reserve. During the period of restriction, the Commission is obliged to assess the quantity of water likely to be available. In assessing the quantity, deductions have to be made for losses and for the special purpose of providing for dilution, lockages and evaporation in the South Australian reach of the Murray. The available water is then divided between N.S.W., Victoria and South Australia in the ratio 5:5:3.

In the post-Dartmouth situation, the South Australian entitlements will be as follows:

(a) the annual entitlement will be increased from 1.55 million megalitres to 1.85 million megalitres. Also, the specified monthly entitlements will be altered, as shown in Table A-1;

(b) in periods of restriction, the available water will be shared equally between the three States.

TABLE A-1
SOUTH AUSTRALIAN MONTHLY ENTITLEMENTS

Month	Monthly Entitlement (Ml/d)[1]	
	Pre-Dartmouth	Post-Dartmouth
July	1,900	3,400
August	3,700	3,900
September	4,700	4,400
October	4,500	5,400
November	5,500	6,100
December	5,300	7,100
January	5,300	7,100
February	5,900	6,600
March	4,500	5,800
April	3,900	4,600
May	3,700	3,200
June	1,900	3,300

(1) The Agreement specifies the entitlement in terms of monthly flow, but Ml/d is used here for consistency with the rest of the paper.

APPENDIX B
DETAILS OF SALINITY CONTROL WORKS

LAKE VICTORIA/BRILKA CREEK (STAGE I)

Lake Victoria, an offstream storage near the South Australian border, has raised groundwater levels adjacent to a number of side channels of the River Murray. One of these is Brilka Creek, which intercepts some of the groundwater, and in the past has added it to the River Murray. The Stage I works prevent Brilka Creek flow to the Murray, and inflows to the Creek evaporate from its surface, unless deliberately released. Stage II (not yet constructed) would involve the damming of one other side channel, and pumping of intercepted groundwater to an inland evaporation basin.

BARR CREEK/LAKE TUTCHEWOP (VIC.)

In this scheme, about 15% of the average annual flow of Barr Creek is diverted to the nearby Lake Tutchewop and three smaller basins for evaporation. However, at certain times much higher proportions than 15% are diverted, with consequent large reductions in river salinity at points downriver.

LAKE HAWTHORN (VIC.)

Lake Hawthorn receives saline drainage from irrigated land in the Mildura-Merbein area. The Lake Hawthorn Scheme consists of works to take water from the Lake to inland evaporating basins at times when outfall to the Murray River is undesirable.

CURLWAA I.A. (N.S.W.)

The Curlwaa I.A. occupies 4,200 ha near the town of Wentworth. The scheme consists of four pumped tubewells which control the level of a groundwater mound which had built up. This scheme serves the dual purpose of protecting land from waterlogging and salinisation, and preventing salt accessions to the River Murray.

RENMARK RESERVOIR (S.A.)

Renmark Reservoir (or Salt Creek) is a side channel of the Murray which once formed part of the irrigation supply system at Renmark. It is no longer included in the supply system, and acts as a collector of saline groundwater. The Stage I scheme dams off Salt Creek, so preventing salt accessions to the river, unless intentional releases are made. Stage II, an interim measure which could be constructed pending permanent evaporative disposal facilities becoming available (Stage III), would comprise pumps, and a pipeline connection to the Dishers Creek evaporation basin. Seepage from this basin would reduce the benefit of any pumping of saline water from Salt Creek.

MILDURA-MERBEIN GROUNDWATER INTERCEPTION (VIC. & N.S.W.)

Irrigation adjacent to this reach of the Murray has created groundwater mounds which cause salt accessions. Pumped tubewells are proposed along both banks of the river to intercept the seepage. Disposal will be by evaporation in inland basins.

NOORA BASIN (S.A.)

The Noora Basin is an inland depression which could be used for evaporation of subsurface drainage piped from irrigated land in the vicinity of Berri, Barmera and Cobdogla. Currently, disposal is to basins close to the river.

LAKE TYRRELL SCHEME (VIC.)

The Lake Tyrrell Scheme would be an extension of the present Barr Creek/Lake Tutchewop Scheme, in which a 90 km channel and pipeline between Lakes Tutchewop and Tyrrell, together with increased capacity pumps on Barr Creek, would enable a much greater proportion of Barr Creek flow to be diverted. If pumping were carried out only at times when river salinities were of concern to users, about 100,000 tonne/year more than the present amount would be diverted to evaporation. The Lake Tyrrell Scheme is part of a proposed 'package' put forward by the Victorian Water Commission, and would have the function of offsetting the effect of proposed outfalling of groundwater from the Shepparton Region.

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